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Development of Wireless Sensor Network for Data Collection and Footwork Training

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Abstract

The Wireless Sensor Network (WSN) is an advanced developing technology. It is applied in this research to develop a Video and Acceleration Data Synchronous Collection and Analysis System in order to collect the video sample and acceleration data synchronously to analyze them after corresponding the frame with acceleration data of table tennis and shot put players. The WSN's characteristics of networking mode, intelligence, wireless data transmission, self-configuration and management, supports of large number of nodes, and self healing, flexibility and mobility, node microminiaturization and low energy cost, etc, allow this system to collect many sensor nodes' data. These sensor nodes could be deployed on many different positions of players' body, such as arms, legs. The video clips and acceleration data could be displayed on the same windows of the system software simultaneously. Coaches and players can review information intuitively and clearly, use them to analyze their performance of technique and strength.

And, a footwork movement training and data collection system which is developed by the same technology is used for table tennis player's movement training and result evaluation. This system can collect the data such as exercise duration time, each movement time. Besides the table tennis, the tennis, basketball, volleyball players could also use this kind of system to guide and monitor the movement ability training.

Keywords: Wireless sensor network; WSN; footwork; video; acceleration; data; collection

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1. Introduction

How to collect data of dynamic movements correctly and assess the training effects accurately based on digital data has now become an important research direction in sports engineering. In the professional sport, skill training and strength training are two all-important components. The research purpose of this project is to explore and select new technology and to develop the instruments and devices which can combine strength training with skill training and testing effectively and enrich the training and testing approaches. In this research, advanced intelligent "Wireless Sensor Network" technology is able to realize the above purpose. The foundational elements of WSN include the sensor, sensor node, communication and network devices, protocols and software.

Compared with traditional sensor technology, the WSN technology has the advantageous features such as digital signal, wireless transmission, network route, two-way signal transmission, etc. The most outstanding features lie in the intelligent collection node, programmable interior, automatic network organization and management according to the protocols.

Its main function is to collect data automatically, to organize the networks and transmit and manage the data automatically and dynamically according to certain rules.

Its basic constituent unit is the sensor node, of which the features are miniature and flexible with low power consumption and low cost. In order to fulfill the functions of collecting, storing and transmitting all the data, the sensor used to collect the parameters is put inside the node with the support of the controller, storage, communication and power supply unit. The WSN is an intelligent sensor network based on the PROFIBUS, which realizes all digital, wireless and open-ended two-way communication between the sensor node and the control equipment and is able to realize the centerless, autonomously organized, dynamic network topology framework. The network structure of the WSN is the network formation technology. It has many kinds of forms and structures, including the centralized, distributed and net structure. Via the wireless sensor node, the data can access the network through the gateway in the mode of multi-hop transmission. At the task management node of the network, the sensor information is managed, classified and processed, after which it is sent to the application users.

Features of the WSN are especially appropriate for solving the problems studied in this project to achieve the research and development goals, for instance, its intellectualization, ability of dynamic self-organized network, anti-interference in data transmission, ability of wireless data transmission, lightweight and miniature nodes, etc.

2. Design

2.1. Video and Acceleration Data Synchronous Collection and Analysis System

One major requirement of the Table Tennis coach is to acquire the information of player's strength, especially the upper limbs' strength in arm swinging and the lower limbs' strength in footwork movements during the technical training. Our design is to measure the acceleration data of the athletes' arms while they are swinging and the lower limbs while they are moving. By use of the acceleration data, the upper and lower limbs' strength can be assessed indirectly.

By further analysis, it is found that after the data of the acceleration are tested, if such data cannot be corresponded and synchronized with the movement process, the effects of the test and analysis will not be visualized. Thus, should be added new functions. In the system, by use of the video technology, the entire technical movement will be corresponded and synchronized with the result of the acceleration. When the movements are observed, corresponding data can be obtained; when the data are analyzed, synchronous movements can be observed.

2.1.1. Criteria

The following criteria must be satisfied for solving the design problems:

- Enable to collect acceleration data from multi position's sensor nodes.
- Acceleration data and Video image can be collected synchronously.
- All data must be transmitted wirelessly, in order not to affect the athletes' normal performance.

2.1.2. Design and Develop

In order to solve design problem, whole task has been divided to the following: (1) Acceleration data collection; (2) Video image capture; (3) Synchronize the (1) with (2).

In the first part, select the Freescale acceleration sensor whose measurement range is 0~100g to develop the node. Put the node into the protective gears such as wristlet, kneecap, ankle support, waist protector, players carry those protective gears on their arms, legs or body. The sensors collect the acceleration data of the players' movement. The RF wireless transceiver in node transmit the data, gateway of system receive the data, via USB port, transfer into software, and record into the database in computer. In the second part, develop the collection, play and saving of video by Microsoft's DirectShow SDK. Link Sony and Canon DV camera via IEEE1394 of computer. Video camera and acceleration sensor are triggered on the same start time point, to collect the data and video, to display on computer's screen.

The data input control flowchart is as the Fig 1,and the collection of video and acceleration data synchronous is as Fig 2.

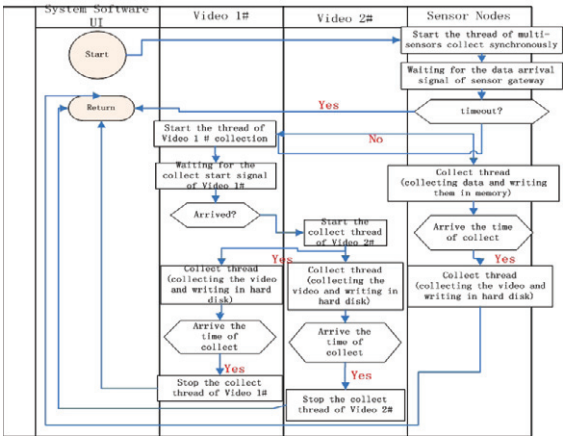

Fig. 1.Data Collection control

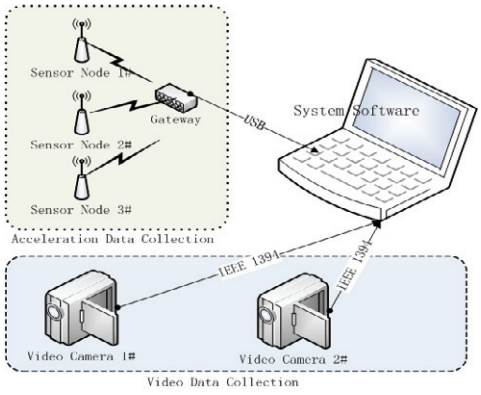

Fig. 2. Synchronize the video and acceleration data

The more function of the system is as the following:

- Project management: Save the node sequence and node configuration with regular data acquisition as a scheme and reduce the workload for configuration of wireless network before acquisition.
- Collection management: Control the Start, Stop/Pause of the sensor nodes in WSN; Control the Capture of Video and the Synchronization of both.
- Devices Management: In the Video Device Management, include device detection and device parameters setup(collect duration, save format of video file) ; in the Sensor Device management, include the sensor node detection and parameters configuration, nodes in network browse and their

status review. All these ensure the well-condition of network deployment and the integrity and accuracy of the collected data.

- Data Management: include data inquiry, display the data in digital, curve or video, look back the historical training information, allow the coaches and players to review the certain data in intuitive way, help the coaches to analyze the problems that might exist in the training.

2.2. Footwork Movement Training and Data Collection System

In most sports, speed and accuracy of movement will influence the performance and results of competition. In the trainings, those related to the ability of footwork movements such as the strength and physical training, response speed and sensibility training even the skill and tactics training are required more and the coaches spend more time and energy on this aspect.

In the meantime, sports injuries of athletes' lower limbs and waists make a rather high proportion among the injured parts. When there are footwork movements such as a sudden stop, sudden direction change and turning-around, etc. Therefore, the significance of footwork movements training not only lies in enhancing their strength and physical abilities, but also in preventing sports injuries caused thereby.

The research objectives are: (1) Select the acceleration sensor to collect the movement data of instrument and human bodies. (2)Develop the sensor network nodes and establish the wireless sensor network.(3)Develop the system management and control software for network management, data collection, training results computation, etc.

According to the above objectives, the main functions of the designed this system are: A certain number of signal (sound or light) generators can be set within the training field range; they send out the signal (sound or light) automatically to guide the athletes to move quickly; when the athletes move to and touch them, a movement is completed; then, another one of them sends out the signal immediately and the athletes move towards the next target; then they move in turn. The signal generators can be placed randomly and the signal generation frequency and locations can be random. In this way, the movement feature in actual competitions can be simulated. The system records the movement completion performances (the time, success rate, etc.) of all the athletes for effect assessments.

Take advantage of the feature of networking for data transmission between the nodes, and lots kind of topology structure, the random of signal given by nodes can be realized. And, the continuity of signal after each touch ensure the continuous movement guidance, simulation of the competition reality mostly, produce well training effect.

3. Results

3.1. Video and Acceleration Data Synchronous Collection and Analysis System

3.1.1. Function of the System:

Sensor node is very small and light. It can be carried on different position of players' body, shall not affect the technical movements of players.

So far, the system can collect the acceleration data from 4 nodes simultaneously at most. It operates in the 2.4GHz frequency band according to IEEE 802.15.4. Nodes are packed by water-proof material to prevent the damage by human eccrine. Power supply is micro lithium-battery which can be charged. The system can work for at least 30 minutes after once charge. Weight of node is 19.5g, weight of battery is 19.2g , volume of node is 50×35×12mm, volume of battery is 40×25×12 mm. By means of connecting two-channel DV digital video camera via IEEE1394 interface (Frame frequency is usually 25 fps) , or via

GigE interface to link 1 high-speed video, the system supports and controls the function of synchronous starting and stopping acquisition of two sets of video cameras, thus can fine control the two sets of video cameras simultaneously. Video File format can be AVI, MPG, WMV and MPEG, etc. Through designing XML format project file, the internal link between the video file and acceleration data file is established while collecting and creating. It is ensured that when the video files are opened, it will automatically determine the presence of corresponding acceleration data and if there is any, the files will be opened together. The video clips and acceleration data can be displayed in multi-windows.

3.1.2. Test and Data:

Players carry the sensor node on waist position with wristlet. Fig 3a to Fig 3b show the synchronous playing of the video of shot-putters' throwing action and after collecting the acceleration signal of wrist. Play the video of athletes' throwing action by frame, and contrast analysis of the wrist acceleration, you can see that the three axis acceleration of wrist increases gradually. On two screen shots of the video, observe the values of the acceleration, is 46.520m/s^2 ,56.439m/s^2 .According to Newton's second law F=ma, obviously, the more the acceleration of wrist is, the more force will put on the shot. Thus, we can determine the athletes' power by acceleration data.

Fig. 3a. Screen shots 1#: video and acceleration

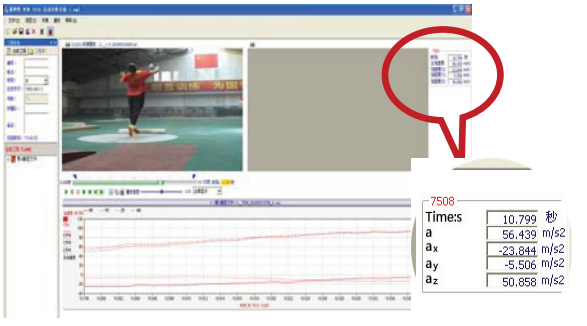

Fig. 3b. Screen shots 2#: video and acceleration

If we attach an acceleration sensor node to a table tennis player's wrist, at the same time collect the video image and acceleration data of the wrist with a racket in his hand, the maximum acceleration of this movement can be 205.835 m/s^2.

3.2. Footwork Movement Training and Data Collection System :

In the Nodes Deploy Window of the software (Fig 4),the nodes quantities in WSN and deployed situation can viewed clearly. In the window of Training Data (Fig 5), results of training can be displayed in chart and bar.

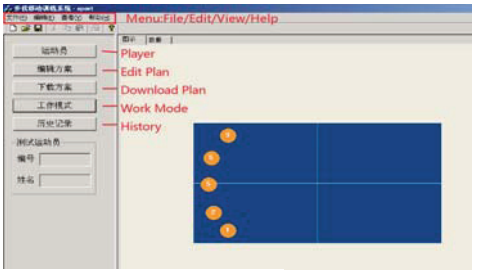

Fig. 4. Nodes Deploy

The Technical

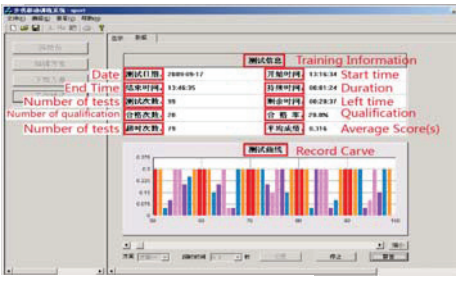

Fig. 5. Training Data Display

Specifications of system (1) Total quantity of nodes: ten.(2) Set mode of nodes: can be placed randomly within the range of the field.(3) Operating mode of nodes: the random mode and custom mode: In the random mode, coaches can add and reduce the nodes arbitrarily within the range of total node quantity; in the custom mode, coaches can set the node quantity, circulation sequence and placement positions.(4) Reliable wireless communication distance: up to 50 meters at least (Blocking by a human body is allowable).(5) Signal generator: High-light LED plus the buzzer.(6) Time interval of two signals: Fixed interval: The interval ranges from 0.5 to 60 seconds and the adjustment step is 0.1 second; Random interval: The interval varies in a range from 0.5 to 60 seconds and the adjustment step is 0.1 second.(7)Training duration: 1 minute ~ 60 minutes, adjustment step: 1 minute.(8)Response touch time: 0.6~60 seconds, players must finish the touch within this range, adjustment step: 0.1 second.(9)Error rate: 1/10,000. (With verification and retransmission).(10)Transmission frequency: 2.4GHz (11)Power consumption: Maximum < 720mW, standby < 400mW (four size-5 alkaline batteries can work continuously for 8 hours).

4. Conclusion

The synchronization of image signal and data collected via wireless sensor networks, achieves that the training of detection is based on the number-based precision, the image-based visualization, and the overall synchronization based on both. The results of the system show that the synchronous collection and playing function provide a kind of practical tool to analyze technique and strength for coaches and athletes. The basic principles and function are applicable in many sports events, having great application potential and prospects.

Footwork training system's functional features determine that other sports events can also use this training system, such as tennis, badminton, basketball, volleyball, football, hockey and ice hockey sports events, which require large playing field. This system can be used to simulate some kinds of movement route, arrange nodes in the field according to the ground-hitting points in actual competition to guide the athletes; in system software, the interval between guidance signal occurrences can also be set according to the time interval between two consecutive ground-hitting points. By simulating such factors as position of ground-hitting point, sequence of guidance signal occurrence and time interval of consecutive ground-hitting points, the effects of conducting footwork training in simulated competition are achieved.

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